African Journal of Biotechnology Vol. 11(6), pp. 1378-1385, 19 January, 2012
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.1909
ISSN 1684–5315 © 2012 Academic Journals

Full Length Research Paper

Competition of rapeseed (*Brassica napus* L.) cultivars with weeds

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Accepted 14 November, 2011

One of the agronomic methods in weeds management is to recognize cultivars possessing high competitive ability with weeds and to recognize the effective characters in order to breed competitive cultivars in weeds sustainable management. Cultivar identification and discrimination has become an important issue in rapeseed breeding programs. A field experiment was carried out at the research station of Islamic Azad University of Firoozabad, Iran in the 2009 to 2010 growing season. The experiment was conducted using split-plot arrangements in a randomized complete block design with three replications. The treatments included two levels of weed (W_0: weed free, and W_1: weedy) as main plots and eight rapeseed cultivars (Modena, Okapi, Sarigol, Licord, Hyola308, Zarfam, RGS003 and SLM046) as sub-plots. Ten plant samples were chosen from the middle part of each row and days from emergence to flowering, days from emergence to physiological maturity, plant height, pod length, pods on main stem, pods per plant, seeds per pod, 1000-grain weight, harvest index and grain yield were determined. The ANOVA results show that weeds resulted in reduction of all traits except pod length. In this investigation, the highest and lowest grain yield in weed free condition was seen in Modena and Okapi, respectively while, the highest and lowest grain yield in weedy condition was seen in Sarigol and Hyola308, respectively. Based on the results of grain yield reduction, ability to withstand competition (AWC) index and cluster analysis, Sarigol cultivar, which had high grain yield in both weed free and weedy conditions, was the best cultivar that has competitive ability with weeds and Hyola308 cultivar was the worst. 1000-grain weight was also the best trait to evaluate cultivars that has competitive ability with weeds for grain yield improvement.

Key words: Competitive ability, weed, grain yield, cultivars.

INTRODUCTION

It is well known that weeds interfere with crop plants, causing serious impacts either in the competition for light, water, nutrients and space or in the allelopathy. In addition to economic considerations, increasing incidence of herbicide resistance in weeds and perceived environmental and human health effects of pesticides have led producers to at least consider a more integrated weed management approach to reduce their high dependence on herbicides (Beckie, 2007). Integral to this approach is the inclusion of competitive crops and cultivars within cropping systems. A competitive crop or cultivar should maintain its yield under relatively low weed interference, while reducing the growth and seed production of weeds against which it is competing (Jordan, 1993). Rapeseed as a slowly growing crop is particularly exposed to severe competition from weeds. Weed suppression by shading only begins after the canopy of rapeseed leaves have grown over the rows and covered the field early. Faster growth of weeds is disadvantageous for light and hence photosynthesis needed for rapeseed plants. Through this light deprivation, less energy is available to crop plant for metabolic production and hence growth, yield and its quality of rapeseed plant will be reduced. In addition, weeds development with rapeseed plant causes severe

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nutrition deprivation (Roshdi et al., 2008). Crop competitiveness is often determined by absolute grain yield under weed free conditions, indicating the yielding ability of the crop, relative grain yield in the presence of weeds indicating crop competitive ability, and weed biomass indicating weed suppression ability (Mortensen et al., 2000).

One of the agronomic methods in weeds management is to recognize cultivars possessing high competitive ability with weeds and to recognize the effective characters in order to breed competitive cultivars in weeds sustainable management (Zimdahl, 2004). Genotype × environment reduces the rate of genetic improvement in crop plants and makes it necessary for test selections over several seasons and sites. Cluster analysis is a useful technique for describing differential yield responses of breeding cultivars grown in diverse environment (Yau and Ortiz-Ferrara, 1994). Cultivar identification and discrimination has become an important issue in rapeseed breeding programs (Mailer et al., 1997). Cluster analysis assigns genotypes into qualitative homogenous groups based on response similarities and also assists to classify genotypes. Whichever, breeding strategy is chosen, stratification of environments is essential (Yau, 1991). The method is based on computation of Euclidean distances among group means and produces a dendrogram showing successive fusion of individuals. In the dendrogram, genotypes are presented on the horizontal axis and the vertical axis shows the amount of Euclidean distances. Greater heterotic effect is generated when clusters are divergent. This information complements the stability parameters (Mahasi and Kamundia, 2007).

A study was conducted from 2003 to 2006 at four sites across semiarid prairie ecoregions in Saskatchewan and Alberta to investigate the productivity and quality of rapeseed (*Brassica napus* L.) and mustard cultivars under weed competition. Four open-pollinated rapeseed cultivars, four hybrid rapeseed cultivars, two rapeseed-quality mustard and two oriental mustard cultivars [*Brassica juncea* (L.) Czern. & Coss.], and two yellow mustard (*Sinapis alba* L.) cultivars were grown under weedy and weed free conditions. When combined across site-years, crop aboveground biomass at maturity and seed yield were reduced by weed interference, except for yellow and oriental mustard. However, seed oil and protein content of cultivars were not affected by weed competition. Among crop types, yellow and oriental mustard were able to maintain biomass and seed yield under weed interference, following the decreasing order of competitiveness by hybrid and open-pollinated rapeseed, then rapeseed-quality mustard (Beckie et al., 2008). Hamzei et al. (2007) revealed that grain yield decreased significantly length of weed interference duration and decreased length of weed free period. Grain yield decreased by 69.39% in the weedy treatment. This yield reduction is related to the lower amount of available nutrients, light and water for the crop plants. Biological yield was also reduced as weed interference durations increased and weed free durations decreased. Full-season weed interference decreased biological yield to about 57.14%. Similar results were reported by Ahmad Khan et al. (2003) and Martin et al. (2001). They showed an increase in grain yield by controlling weeds and yield loss as the duration of weed interference with rapeseed increased. Messean (1997) also indicated that losses in rapeseed yield in France due to weeds are estimated to be 15%.

A greenhouse study was conducted to assess the competitive ability of yellow mustard and rapeseed with wild oat in 1999 and 2000, using replacement series interference experiments to relate the results to plant development stages. Yellow mustard, regardless of its proportion in mixture, reduced aboveground biomass of wild oat from 33 to 66%, leaf and tiller number from 34 to 36%, and panicle production (58%) when compared with wild oat in monoculture. Rapeseed did not affect wild oat biomass in mixtures. Yellow mustard per plant biomass in 2000 and inflorescence production in 1999 decreased by 30 and 20% with increased density of yellow mustard in mixtures. Yellow mustard biomass was not affected by the addition of wild oat to the mixture, indicating the greater importance of intraspecific competition between yellow mustard relative to interspecific competition with wild oat (Daugovish et al., 2002). Dezfooli (2000) reported that uncontrolled natural infestation of wild mustard reduced light penetration, growth and yield of spring wheat. Wild mustard competition caused 44 and 51% reduction in grain yield and final biomass of spring wheat, respectively.

This study was undertaken to determine competitive ability of eight rapeseed (*B. napus* L.) cultivars with weeds and evaluate the relationship between competitive ability of rapeseed cultivars with weeds and grain yield to recognize cultivars possessing high competitive ability with weeds to improve breeding programs.

MATERIALS AND METHODS

Eight rapeseed genotypes: Modena (G1), Okapi (G2), Sarigol (G3), Licord (G4), Hyola308 (G5), Zarfam (G6), RGS003 (G7) and SLM046 (G8) of winter rapeseed were planted in field at the research station of Islamic Azad University of Firoozabad, Iran (28.35°N, 52.40°E and 1327 m above sea level) in the 2009 to 2010 growing season. Treatments were arranged in a split plot design based on randomized complete block design (RCBD) with three replications. Main plots were weedy and weed free conditions and subplots were the genotypes. The soil was ploughed and cultivated before planting. Each plot consisted of six rows, 3 m in length and spacing of 10 cm between plants within row and 30 cm between rows.

Based on the soil test, fertilizer treatments were applied at rates of 150 kg ha^{-1} of ammonium phosphate, 150 kg ha^{-1} of potassium sulphate and 60 kg ha^{-1} N prior to planting plus an additional 60 kg ha^{-1} N topdressed at 7- to 9-leaf stage. The planting date was December 14, 2009. All plots were irrigated normally throughout the

Table 1. Analysis of variance for the studied traits of eight rapeseed cultivars.

S.O.V.	df	Mean of squares									
		Days from emergence to flowering	**Days from emergence to physiological maturity**	**Plant height (cm)**	**Pod length**	**Pods on main stem**	**Pods per plant**	**Seeds per pod**	**1000-grain weight (g)**	**Harvest index (%)**	**Grain yield (g plant^{-1})**
Block	2	5.65**	30.33**	0.08 ns	0.72**	45.84**	17.14ns	7.81ns	0.50**	0.0008^{ns}	98414.49^{ns}
Weed	1	229.69**	438.02*	1.51*	0.44ns	463.33*	3056.66**	285.19*	1.23*	0.0628*	25853535.64**
E (a)	2	0.81	9.33	0.06	0.25	4.71	16.40	3.69	0.04	0.0013^{ns}	94020.09
Genotype	7	498.40**	316.40**	2.14**	0.53**	370.87**	328.70**	14.34^{ns}	2.85**	0.0013^{ns}	1954942.89**
Weed × Genotype	7	4.02**	3.26^{ns}	0.01 ns	0.10ns	15.21**	214.38**	2.31^{ns}	0.07*	0.0010^{ns}	467296.90**
Block × Genotype	14	2.38*	10.93*	0.19**	0.55**	14.76**	21.32ns	5.81^{ns}	0.24**	0.0009^{ns}	44251.21^{ns}
E (b)	14	0.65	4.21	0.02	0.10	2.69	13.31	6.87	0.02	0.0009	59132.78
%CV		0.80	1.09	1.37	4.86	5.48	4.77	17.25	4.41	6.20	11.29

ns, * and **, not significant, significant at the 5 and 1% levels of probability, respectively.

season. In weed free plots, weeds were removed completely by hand weeding during the growth period. Ten plant samples were chosen from the middle part of each row and were signed by labels and the border parts were left out. Then, the labeled plant samples were measured for the following traits: days from emergence to flowering, days from emergence to physiological maturity, plant height, pod length, pods on main stem, pods per plant, seeds per pod, 1000-grain weight, harvest index and grain yield. Seed yield was measured at physiological maturity and yield was adjusted to 12.5% seed moisture content.

Data were tested for skewness, kurtosis and normality by Minitab (1998) statistical software. Then, analysis of variance in a split plot design based on randomized complete block design (RCBD) and comparison of quantitative traits means based on Duncan's new multiple range test (DNMRT), were performed in SAS (2001). Interaction effects and cluster analysis were carried out by MSTATC and Minitab softwares, respectively. Excel software was used for drawing of figures. Ability to withstand competition (AWC) was estimated as the ratio (Jannink et al., 2000):

$$AWC = (\frac{Vi}{Vp}) \times 100$$

Where, Vi = grain yield of cultivar i in weedy condition and Vp = grain yield of cultivar i in weed free condition.

RESULTS AND DISCUSSION

Weed × genotype interaction effects were highly significant for days from emergence to flowering, pods on main stem, pods per plant, 1000-grain weight and grain yield, indicating that genotypes did not respond to the conditions similarly (Table 1). $W_0 \times G_4$ and $W_1 \times G_5$ interaction effects had the highest and lowest number of days from emergence to flowering (113.67 and 82.33, respectively). The highest number of pods on main stem was related to $W_0 \times G_4$ and $W_1 \times G_2$ interaction effects (46 and 14.4, respectively). $W_0 \times G_3$ and $W_1 \times G_2$ interaction effects had the highest and lowest number of pods per plant, respectively. The highest amount of 1000-grain weight was related to $W_0 \times G_1$ interaction effect (4.71 g), and the lowest 1000-grain weight were related to $W_1 \times G_2$ and $W_1 \times G_6$ interaction effects (2.37 and 2.42 g, respectively). $W_0 \times G_1$ and $W_0 \times G_3$ interaction effects had the highest amount of grain yield (3795.13 and 3705.03 g plant^{-1}, respectively) and $W_1 \times G_5$ interaction effects had the lowest amount of grain yield (829.67 g plant^{-1}). Non-significant weed × genotype interaction effects indicated that selection for days from emergence to physiological maturity, plant height, pod length, seeds per pod and harvest index might be effective for a broad range of conditions.

Results of ANOVA reveal that weed effects were statistically significant for days from emergence to flowering, days from emergence to physiological maturity, plant height, pods on main stem, pods per plant, seeds per pod, 1000-grain weight, harvest index and grain yield, indicating that these traits are influenced by weedy conditions. Weed effect was not significant (P>0.05) for pod length indicating that this trait is not influenced by weedy conditions (Table 1). Pods on main stem and pods per plant were reduced under weedy condition which was probably related to the lower fertilization of flowers or more flowers shattering before pollination due to weed infestation (Table 2). Seeds per pod trait was seriously affected by

Table 2. Means value for different traits of rapeseed (*B. napus* L.) under weed free and weedy conditions.

Trait	W_0	W_1	Percentage decrease (%)
Days from emergence to flowering	103.04[a]	98.67[b]	4.21
Days from emergence to physiological maturity	192.04[a]	186[b]	3.15
Plant height (cm)	137.71[a]	129.5[b]	5.96
Pod length	6.49[a]	6.30[a]	2.93
Pods on main stem	33.02[a]	26.80[b]	18.83
Pods per plant	84.47[a]	68.51[b]	18.89
Seeds per pod	17.63[a]	12.76[b]	84.34
1000-grain weight (g)	3.48[a]	3.16[b]	9.20
Harvest index (%)	0.521[a]	0.448[b]	16.29
Grain yield (g plant^{-1})	2886.89[a]	1419.11[b]	50.84

Means in each row, followed by similar letter(s) are not significantly different at 5% probability level, using Duncan's multiple range test. W_0, Weed free condition; W_1, weedy condition.

weeds and it was reduced (84.34%) under weedy condition. Therefore, seeds per pod was not a suitable trait to evaluate cultivars for competitive ability with weeds (Table 2).

The decrease in percent of 1000-grain weight under weedy condition was 9.20. Considering that 1000-grain weight is one of the major components of grain yield, the inferiority of 1000-grain weight reduction is important in plant breeding (Ivanovska et al., 2007). Therefore, we can use 1000-grain weight trait to evaluate the studied cultivars for competitive ability with weeds.

Harvest index was reduced under weedy condition. This reduction was related to the higher vegetative growth of cultivars when compared with generative growth due to the higher transfer of photosynthesis materials to shoot. As a result, biological yield was more affected by the weeds than grain yield to reduce harvest index (Table 2). Grain yield was affected under weedy condition and it was reduced to about 50.84% when compared with weed free condition (Table 2). Blackshaw et al. (2002) also reported similar results for pods per plant and seeds per pod. The results showed that the studied rapeseed cultivars were significantly different in all traits, except for seeds per pod and harvest index, indicating the existence of genetic variability for the majority of the studied traits. Roshdy et al. (2008) similarly, revealed that genotype effects were highly significant for pods per plant, seeds per plant and grain yield. Lemerle et al. (2010) also reported similar results for grain yield.

Means comparison showed that Licord and Okapi cultivars had the highest number of days from emergence to flowering and days from emergence to physiological maturity in weed free and weedy conditions. Hyola308 cultivar had the lowest number of days from emergence to flowering and Zarfam cultivar had the lowest number of days from emergence to physiological maturity in weed free and weedy conditions. In plant breeding, decreases in days from emergence to flowering and physiological maturity traits are suitable for grain yield improvement (Yadava and Singh, 1999). Therefore, these cultivars seem to be suitable. Okapi and Licord cultivars also had the highest amount of plant height and Zarfam cultivar had the lowest amount of plant height in weed free and weedy conditions. Considering that increased plant height can lead to decrease grain yield via lodging and breaking, we can use Zarfam cultivar to decrease plant height (Table 3).

Okapi and Modena cultivars had the highest amount of pod length in weed free condition. All cultivars had statistically similar pod length in weedy condition, indicating the effects of weeds on pod length to decrease its variability. The highest number of pods on main stem was related to Licord and RGS003 cultivars and Okapi cultivar had the lowest number of pods on main stem in weed free and weedy conditions.

Sarigol and Licord cultivars had the highest number of pods per plant and Hyola308, SLM046 and Okapi had the lowest number of pods per plant in weed free condition (Table 3). Zarfam and Okapi cultivars had the highest and lowest number of pods per plant, respectively, in weedy condition. SLM046 and Sarigol cultivars had the highest and lowest number of seeds per pod, respectively, indicating the effects of weeds on seeds per pod to increase its variability. Modena cultivar had the highest amount of 1000-grain weight and Zarfam and Okapi cultivars had the lowest amount of 1000-grain weight in weed free and weedy conditions (Table 3).

The dendrograms of cluster analysis using Ward method are illustrated in Figures 1, 2 and 5. In the dendrograms (Figures 1 and 2), traits are presented on the horizontal axis and the correlation coefficient distances on the vertical axis. The studied traits were grouped into three clusters in weed free and weedy conditions. Based on the results, seeds per pod was located in the first cluster, grain yield, 1000-grain weight, pods per plant and pods on main stem were placed in the second cluster and other traits were located in the third

Table 3. Effect of genotype on studied traits in rapeseed under weed free and weedy conditions.

Treatment	Cultivar	Mean									
		Days from emergence to flowering	Days from emergence to physiological maturity	Plant height (cm)	Pod length	Pods on main stem	Pods per plant	Seeds per pod	1000-grain weight (g)	Harvest index (%)	grain yield (g plant^{-1})
Genotype (weed free plot)	Modena	103.67^{d}	190.67^{bc}	139.1^{b}	6.85^{a}	34.97^{b}	80.76^{b}	15.47^{a}	4.708^{a}	0.533^{a}	3795.1^{a}
	Okapi	111.67^{b}	202.67^{a}	162.2^{a}	6.92^{a}	20.63^{d}	73.5^{c}	18.73^{a}	2.792^{d}	0.529^{a}	1333.8^{d}
	Sarigol	94.67^{f}	186^{cd}	126.9^{bc}	6.04^{bc}	27.73^{c}	104.81^{a}	15.4^{a}	3.952^{b}	0.511^{a}	3705^{a}
	Licord	113.67^{a}	203^{a}	155.2^{a}	6.39^{abc}	46^{a}	103.16^{a}	17.8^{a}	2.995^{cd}	0.491^{a}	3179.3^{b}
	Hyola308	86^{g}	188.67^{bc}	129.4^{bc}	6.47^{abc}	34.33^{b}	72.27^{c}	17.93^{a}	3.492^{bc}	0.489^{a}	2624.5^{c}
	Zarfam	100.67^{e}	182^{d}	119.5^{c}	5.92^{c}	25.93^{c}	82.84^{b}	19.73^{a}	2.683^{d}	0.541^{a}	2987.7^{bc}
	RGS003	107^{c}	191^{bc}	130.9^{bc}	6.59^{abc}	42.13^{a}	85.88^{b}	16.93^{a}	4^{b}	0.521^{a}	2765.8^{bc}
	SLM046	107^{c}	192.33^{b}	138.5^{b}	6.71^{ab}	32.4^{b}	72.53^{c}	19.07^{a}	3.25^{cd}	0.551^{a}	2703.9^{bc}
Genotype (weedy plot)	Modena	101.33^{b}	184.33^{c}	131^{bc}	6.34^{a}	23.23^{b}	65.53^{b}	10.4^{b}	4.108^{a}	0.421^{a}	1600.2^{bc}
	Okapi	108.33^{a}	193.67^{b}	151.7^{a}	6.44^{a}	14.4^{c}	65.43^{b}	14.33^{ab}	2.367^{e}	0.468^{a}	907.4^{e}
	Sarigol	91.33^{c}	179.33^{de}	119.8^{cd}	5.91^{a}	24.58^{b}	68.8^{ab}	10.93^{b}	4.11^{a}	0.450^{a}	2274.6^{a}
	Licord	109.67^{a}	198.67^{a}	143.2^{ab}	6.27^{a}	39.67^{a}	71.4^{ab}	11.27^{ab}	2.733^{de}	0.460^{a}	1255^{d}
	Hyola308	82.33^{d}	182.33^{cd}	122.1^{cd}	6.03^{a}	25.5^{b}	68.13^{ab}	13.67^{ab}	3.125^{bcd}	0.433^{a}	829.7^{e}
	Zarfam	93.33^{c}	177^{e}	109.8^{d}	6.08^{a}	23.89^{b}	74.73^{a}	12.8^{ab}	2.417^{e}	0.458^{a}	1383.9^{cd}
	RGS003	102^{b}	186.33^{c}	124.8^{c}	6.56^{a}	34.67^{a}	68.4^{ab}	13.47^{ab}	3.583^{ab}	0.440^{a}	1770.3^{b}
	SLM046	101^{b}	186.33^{c}	133.7^{bc}	6.74^{a}	28.48^{b}	65.63^{b}	15.2^{a}	2.867^{cde}	0.456^{a}	1331.8^{cd}

ns, * and **, not significant, significant at the 5 and 1% levels of probability, respectively. Means in each column, followed by similar letter(s) are not significantly different at 5% probability level, using Duncan's multiple range test.

cluster in weed free condition, indicating that pods per plant, pods on main stem and 1000-grain weight had the higher relationship with grain yield when compared with other traits (Figure 1). Modena and Sarigol cultivars surpassed the six other cultivars in grain yield in weed free condition. The superiority of these cultivars was probably related to 1000-grain weight and pods per plant, respectively. Licord cultivar had high grain yield which was probably due to high 1000-grain weight in weed free condition. Okapi cultivar had the lowest amount of grain yield in weed free condition. The inferiority of this cultivar was probably related to the lowest amount of 1000-grain weight, pods per plant and pods on main stem. These results were confirmed by cluster analysis (Figure 1). The positive relationship between grain yield and 1000-grain weight were reported by Mekki (2003) and Roshdy et al. (2008).

Based on cluster analysis of studied traits under weedy condition, grain yield and 1000-grain weight was located in the first cluster, pods on main stem was placed in the second cluster and other traits were located in the third cluster, indicating that 1000-grain weight followed by pods on main stem had the higher relationship with grain yield when compared with other traits (Figure 2). Sarigol cultivar had the highest amount of grain yield in weedy condition which was probably due to the highest 1000-grain weight (Table 3). On the other hand, Okapi cultivar had the lowest grain yield in weedy condition which was probably due to the lowest 1000-grain weight (Table 3). Modena cultivar had the lowest grain yield in weedy condition which was probably due

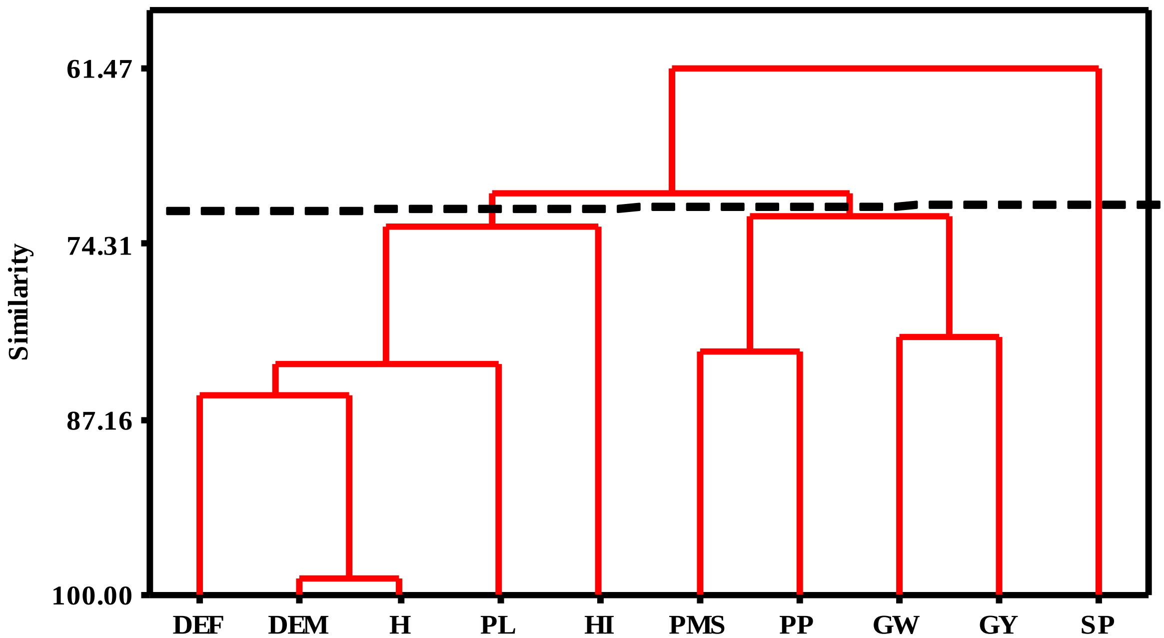

Figure 1. Cluster analysis of studied traits under weed free conditions using Ward method. DEF, Days from emergence to flowering; DEM, days from emergence to physiological maturity; H, plant height; PL; pod length; PMS, pods on main stem; PP, pods per plant; GW, 1000-grain weight; HI, harvest index; GY, grain yield; SP, seeds per pod.

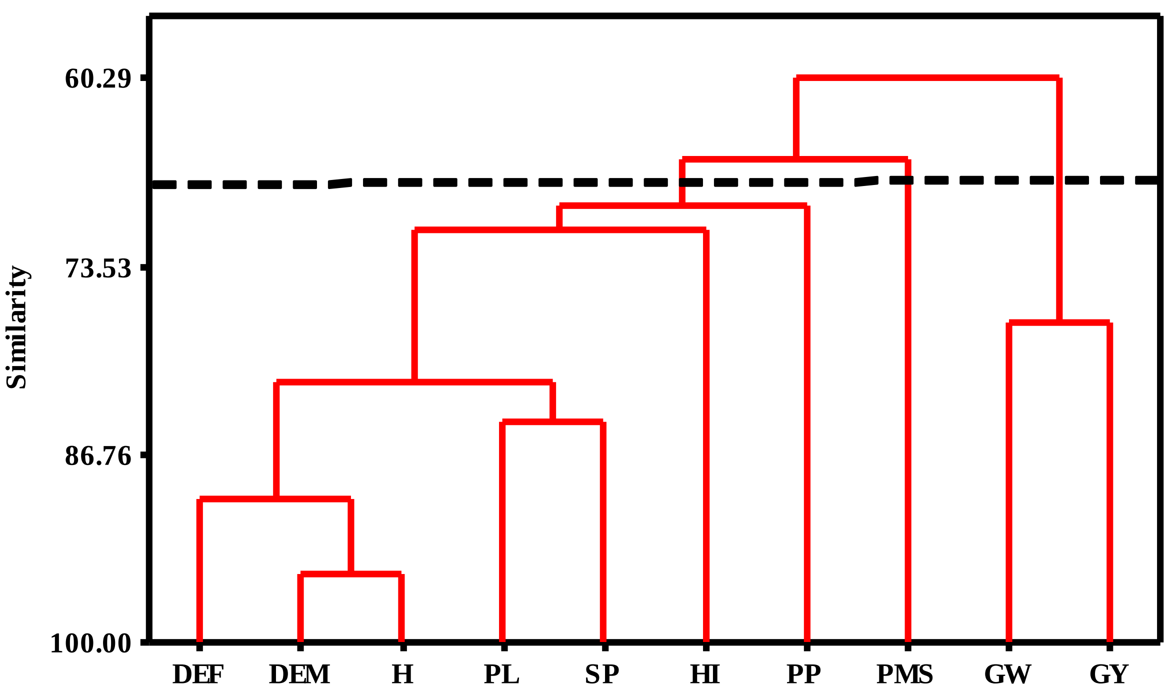

Figure 2. Cluster analysis of studied traits under weedy condition using Ward method. DEF, Days from emergence to flowering; DEM, days from emergence to physiological maturity; H, plant height; PL; pod length; PMS, pods on main stem; PP, pods per plant; GW, 1000-grain weight; HI, harvest index; GY, grain yield; SP, seeds per pod.

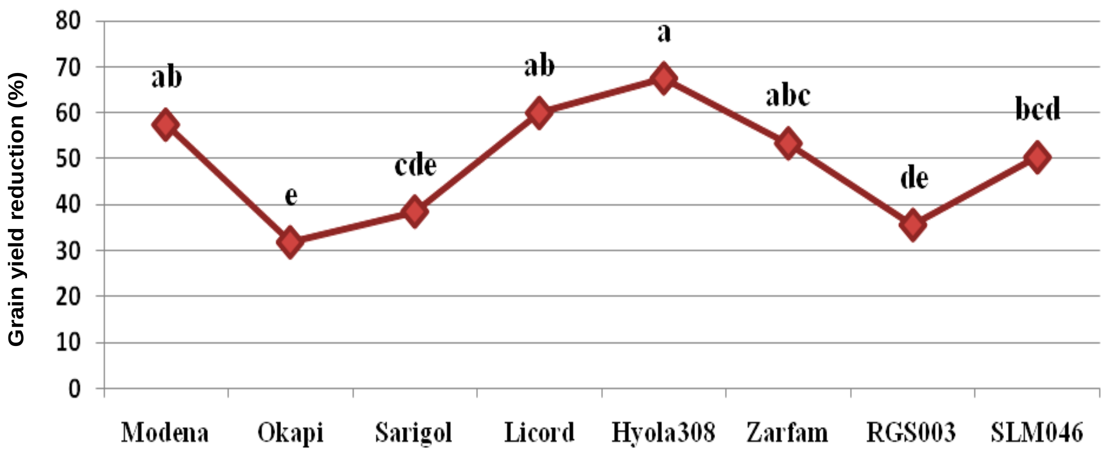

Figure 3. Percentage of grain yield reduction of eight rapeseed cultivars with weed infestation.

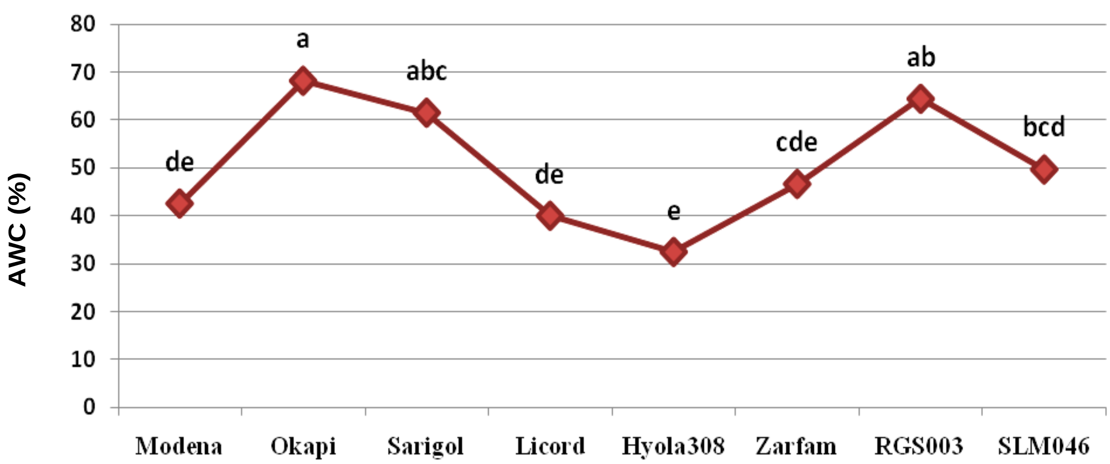

Figure 4. AWC percentage of eight rapeseed cultivars with weed infestation.

to the lowest pods per plant and seeds per pod. These results were confirmed by cluster analysis (Figure 2).

The percent of grain yield reduction of cultivars due to weed infestation ranged between 31.8 and 67.6% for Okapi and Hyola308, respectively (Figure 3) which is related to significance of weed × genotype interaction effect as well as different genetic potential of rapeseed cultivars for grain yield components.

The percent of AWC was also estimated to be between 32.4 and 68.2% for Hyola308 and Okapi, respectively (Figure 4). The superiority of Okapi cultivar for AWC percent was related to the low grain yield in weed free condition while, the inferiority of Hyola308 for AWC percent was related to the low grain yield in weedy condition. Sarigol cultivar had high AWC which was related to the high grain yield in weedy condition but RGS003 cultivar, which possessed high AWC, had low grain yield in weedy condition. Zarfam and SLM046 cultivars had moderate AWC due to low grain yield in weedy condition. Modena and Licord cultivars had low AWC which was related to low grain yield in weedy condition. Therefore, there was no relationship between competition ability with weeds and grain yield in weed free condition. Gill and Colemen (2000) reported similar results in Australia.

In the dendrogram (Figure 5), genotypes are presented on the horizontal axis and the Euclidean distances on the vertical. Based on cluster analysis of rapeseed cultivars for AWC, the genotypes were grouped into three clusters irrespective of the geographical divergence. Based on the results, Okapi, Sarigol and RGS003, which had the highest AWC, were located in the first cluster, Zarfam and SLM046, which had moderate AWC, were located in the second cluster and Modena, Licord and Hyola308 cultivars, which had the lowest AWC, were placed in the third cluster (Figure 5) , confirming the above results.

Generally, based on the results of grain yield reduction, AWC index and cluster analysis, Sarigol cultivar, which

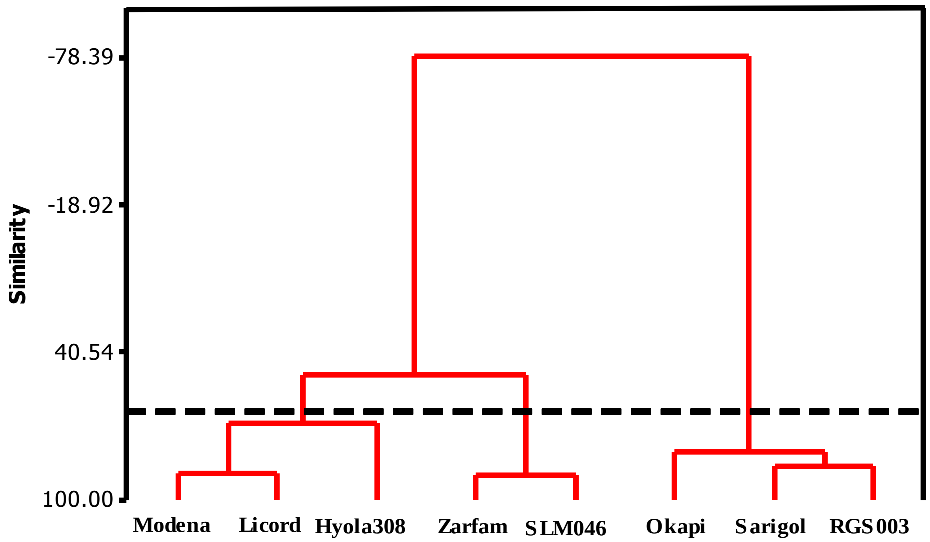

Figure 5. Cluster analysis of eight rapeseed cultivars for AWC using Ward method.

had high grain yield in both weed free and weedy conditions, was the best cultivar that had competitive ability with weeds and Hyola308 cultivar was the worst.

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